Trial Application of the UTMS Dynamic Route Guidance Systems

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ABSTRACT

Universal Traffic Management System (UTMS) (1) and Tokyo Metropolitan Police Department are planning to realize the interactive Centrally Determined Route Guidance (CDRG) (2). The trial application has begun in spring of 1996. According to plans at UTMS, the ultimate aim for DRGS is to reduce congestion through traffic assignment. However, until in-vehicle units become sufficiently widespread to enable this, DRGS will guide each vehicle along its optimum route.

The in-vehicle unit sends out the driver’s destination the moment it enters into the communication zone of an infrared beacon. It finishes receiving information such as the route by the time it leaves the communication zone. The system selects the optimum route using link travel time data which is gathered by the traffic control system. Therefore, even in the early stages of its adoption when it cannot obtain large quantities of travel time data measured by in-vehicle units, the system can still provide guidance relating to the shortest route in terms of time required. The system provides the predicted travel time to the destination together with the route.

The trial application is divided into three sections. The first section is a trial application relating to the basic performance of the system. The second section is an off-line simulation of the system using actual data. The third section is a field trial application which involves driving vehicles equipped with in-vehicle units.

This paper reports on the structure of the system, details of the route service, route selection algorithms, plans for trial application and part of the results of the trial application.

INTRODUCTION

Traffic congestion occurs daily in large cities in Japan. We are making traffic management more advanced in order to cope with this problem. At the same time, car navigation equipment was developed some years ago and drivers starting demanding traffic information in the form of data from which the fastest route to a driver's destination could be located.

To meet these needs, we decided to adopt interactive CDRG as a means of helping to reduce traffic congestion in the future. In this system on optimum route according to the destination of each vehicle is recommended from a center.

National Police Agency decided in 1992 to add a new infrastructure equipped with two-way communication between the ground and vehicles (that is, infrared beacons) to the existing traffic control system. If these beacons and in-vehicle units become more widely used and can identify individual vehicles, it will be possible not only to make the traffic control system more advanced but also to implement several new traffic management measures.

As beacons and in-vehicle units come to be used by more and more drivers, the police, who administer traffic management, will be able to ascertain two new important traffic parameters. One is travel time within a road section and the other is Origin-Destination (O-D). If the travel time can be determined, signal control becomes possible based on constant and direct evaluation of the effectiveness. In addition, travel time information can be provided to the driver. Determining the OD of a vehicle allows traffic conditions to be predicted very accurately. This enables appropriate signal control and provision of information in anticipation of traffic movements.

DRGS is one sub-system which has been made possible by the diffusion of two-way communication between the ground and vehicles. It receives its destination from a vehicle and not only notifies the driver of the optimum route but also fulfills the important role of relieving traffic congestion.

DRGS AS ENVISIONED FOR UTMS

Two Prerequisites for Implementation in Japan

Since traffic control systems have already been set up in Japan, congestion length on major routes can be measured using vehicle detectors. A technique has also been developed for estimating the travel time from the congestion length (3,4). Therefore, even at the stage where in-vehicle units have not yet become widely used, this system can create route information to be provided to in-vehicle units by using traffic information obtained by the traffic control system.

In Japan, stand-alone car navigation equipment is rapidly being adopted by drivers. The Vehicle Information and Communication System (VICS), which went into operation this spring, provides the travel time for each link in a road network for routes along which infrared beacons have been installed. It provides this information to the in-vehicle units which measure the time required to pass through the link and send it to the infrared beacon. That enables vehicles to realize LDRG, so that we are hoping that many drivers will add communication equipment which provides two-way communication to their car navigation equipment.

Adoption of Interactive CDRG

The system of dynamic route guidance can be divided into Locally Dynamic Route Guidance (LDRG), broadcast-type CDRG, and interactive CDRG. As previously been stated, two-way communication between ground and vehicle has been realized in Japan, and we decided to adopt interactive CDRG. as the system for DRGS. This system provides the optimum route decided upon by the center in accordance with the destination of each vehicle. Therefore, it can assign vehicles along road networks according to traffic conditions and so has the potential in the future to contribute to easing of traffic congestion.

Multimode DRGS Proposed in This Report

In-vehicle units can provide even more convenient route guidance by skillfully combining information provided by CDRG of DRGS with the LDRG function provided by the in-vehicle units.

LDRG can select a route from the road network including local streets using only the in-vehicle database and if it has travel time information which is provided by the center, it can take this into consideration when selecting a route. However, it cannot select a route easily based on predicted conditions.

On the other hand, CDRG does not include regional roads or local streets which have little traffic. It handles major roads which are covered by the traffic control systems. Therefore, route guidance by CDRG is suitable for selection of long-distance routes but LDRG is more suitable for short-distance routes of a few kilometers.

We created the multi mode DRGS by combining the features offered by CDRG and LDRG. The most likely scenario for use of the route guidance function provided by multi mode DRGS is as follows: The driver will first use LDRG from the origin to get onto a major road and will then use CDRG along major roads. Upon nearing the destination, the driver will again switch to LDRG and travel on local roads to the final destination.

To give the driver freedom of choice of a route, CDRG proposes several routes. The driver selects one of these routes. The multi mode DRGS in-vehicle unit which is equipped with a map database will probably be able to perform the selection automatically.

System of Providing Information

In-vehicle units which support CDRG can be roughly divided into two types according to the display method. One type is a low-priced figure-type in-vehicle unit which shows the route supplied by CDRG on a simple figure. It is expected that there will be great demand for this type among commercial vehicles which travel frequently within a relatively small area, especially the congested city center. However, as the price of electronic instruments comes down, the second type, a map-type in-vehicle unit which is equipped with a map database, will probably take over the market in the future. Therefore, CDRG provides information aimed principally at map-type in-vehicle units but which is also extremely useful on figure-type in-vehicle units.

CDRG provides the in-vehicle unit with one to three routes to the destination. The system determines these routes based on different criteria, so the in-vehicle unit has to select a preferred route from among these three routes. The system provides not only the link number of each route but also the length of the route and the names of intersections which the vehicle will pass through on the way. This enables drivers which use the figure-type in-vehicle unit to see the features of each route easily. There are also plans to provide the travel time which this system predicts is required to drive along the route as well as traffic information relating to the route.

When in-vehicle units have become so widely used that they can assign traffic along road networks, CDRG will select and provide one route from among several in accordance with a traffic assignment schedule when assigning traffic along road networks.

SYSTEM CONSTRUCTION

System Structure

Figure 1 shows the basic structure of DRGS. Every five minutes, the central unit calculates optimum routes for each beacon based on the concept that all links within the vicinity of a beacon can be a destination. It sends this information to the relevant beacon. The beacon accumulates this route information sent by the center and, each time an in-vehicle unit passes through the communication zone, the beacon receives the destination expressed as a link number from the in-vehicle unit and immediately selects and provides to the in-vehicle unit routes depending on the destination. When a vehicle is traveling along a road, the in-vehicle unit can receive optimum route information each time the vehicle passes through the communication zone of a beacon. The DRGS center receives travel time information necessary for calculating the optimum route from the traffic control system.

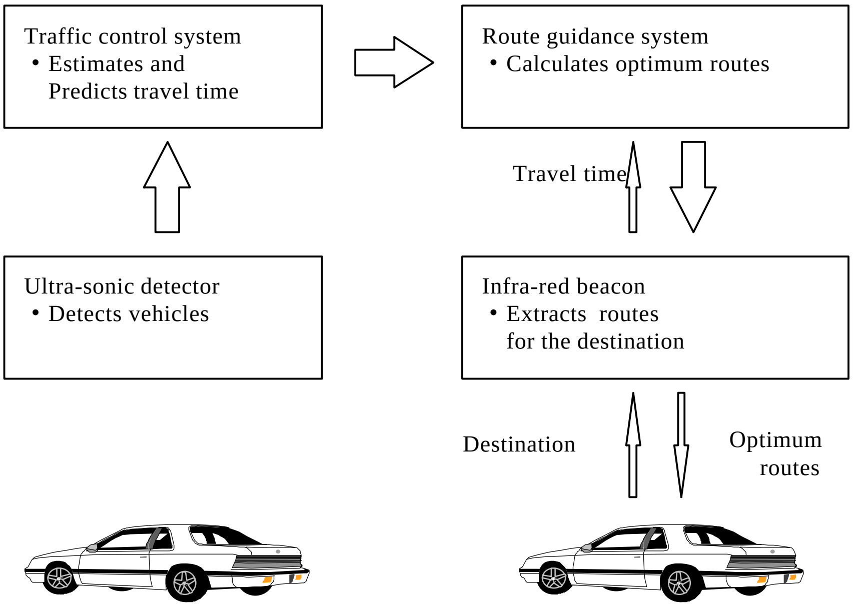

Figure 1 Basic structure of the first stage of DRGS

Target System in The First Stage

The cost of maintaining communication lines which transfer target provision information from the center to the beacons so that the information can be forwarded to in-vehicle units is high. It is uneconomical from the viewpoint of cost effectiveness to run high maintenance costs in the early stage of the system when in-vehicle units are not so widely used. Therefore, in the first stage, we aim to build a system which is most convenient to drivers using low-cost lines and within the capacity that can be transferred using such lines. Then, as in-vehicle units come to be more widespread, we intend to make the system more advanced. Table 1 compares the system in the first stage with the target future system.

Table 1 Service by the future system and by the first stage system

Item	Future system	First stage system
Number of routes to be provided	Three routes : Surface streets only or include toll roads responding to the driver’s choice	Two routes : Surface streets only and include toll roads responding to the driver’s choice
Area of detailed route	30km	20km
Predicted travel time	Average and Maximum	Average
Traffic information relating to the route	Provided by display and voice	Not provided
Names of way points	Provided by display and voice	Provided by display
Transmission speed	64kbps	9,600bps

Method of Route Selection

The optimum routes to all links are expressed as a route tree from the Location of the beacon. Figure 2 shows an example of a route tree to link 1-11, where link 2, link 4 and link 10 are the upstream link of link 3, link 5 and link 11 along the optimum route respectively. In CDRG, the center normally calculates the tree according to the information renewal cycle (five minutes) and sends it to the beacon. According to this method, however, slight fluctuation in travel time data which is used for route calculation causes a significant difference in the optimum route that is given as the result of calculation.

Therefore, a different optimum route may be provided each time the driver passes a beacon and the driver may become confused. To combat this, we decided to adopt a method which prepares several route trees in advance which may possibly serve as the optimum route and selects the route which is optimum at the time. This method has the advantage that it can provide the driver with a stable optimum route even if there are unstable small fluctuations in the travel time data obtained on-line from the field. The idea is that when the networks are restricted to reduce excessive divergence of an optimum route, a near-optimum route not much worse than the true optimum route could be obtained if the restriction is adequately done.

In the actual system, the optimum route is obtained by following the procedure; step 1-2 is done off-line and step 3, on-line.

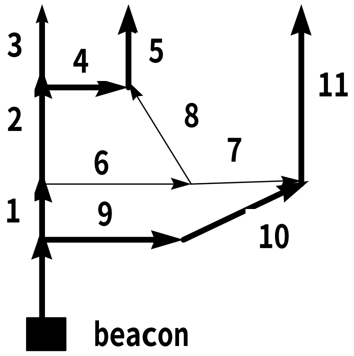

Figure 2 Route tree

Step 1-Calculation of Basic Trees

Trees for an origin are obtained with respect to different departure times chosen to be evaluated under traffic conditions as divergent as possible, and calculated in accordance with the rule that route travel time to every link within a certain area of the origin is the smallest. These trees (basic trees) are used afterwards to gather a set of candidate trees from. Where route travel time is the summation of estimated travel time of each link which is obtained from detector information (3,4) and stored.

Step 2-Selection of A Set of Candidate Trees

A particular combination of N trees gathered from the basic trees is determined so that the near-optimum routes to all destinations along those N trees are totally as close as possible in route travel time to the true optimum routes calculated without network restriction for a variety of traffic conditions and combinations of basic trees. In this process, estimated travel time is used again. Such a set of N trees are the candidate trees that are created

Step 3-Selection of Optimum Routes

The near-optimum route to each destination is selected from a set of N candidate trees every 5 minutes under current traffic conditions. In the selection, route travel time is calculated using predicted travel time of each link which is obtained from detectors information (4).

This method of route selection has one great disadvantage, which is that it cannot provide an appropriate route when traffic conditions become irregular. We intend to shift to the method whose response is improved within several years after starting practical operation of DRGS.

Required Transmission Capacity Between The Center and The Terminals

We calculated the transmission capacity required to transmit the necessary information between the center and the terminals to provide the services in the first stage. The results showed that about 80 kilobytes are required per intersection and that it takes about three minutes to transmit this information at 9,600 bps. We expect that if we adopt a system that sends only the information that differs from the previously transmitted information, the transmission amount can be further reduced.

In the future system, a transmission speed of 64 kbps will be necessary.

Requirements Regarding The Processing Performance of The Infrared Beacon

The infrared beacon must perform all processing and send the route while the in-vehicle unit is within the communication zone. The time available for the beacon to do process such as a determination of the route is evaluated to be less than 31.2 ms. While we measured the processing time of the beacon of the first stage, and got 3.1 ms of a total route search processing time at most for one lane, making sure that it's within the available time. Furthermore, the entire services as future system listed in Table 1 are estimated to require about 21 ms of processing time from the comparison of the amount of data with that in the first stage. That value is also within the available time, and it turns out that we will be able to provide all the services which are the goal of the future system.

Amount of Transmission Data Sent to The In-Vehicle Unit

We designed a transmission format suitable for DRGS services. In UTMS, the amount of transmission data to be sent from the infrared beacon to the in-vehicle unit is set at about 10 kilobytes in total. DRGS will use about 0.3 kilobyte of this in the first stage.

We are hoping that electronics technology will also have advanced by the time in-vehicle units become more widespread and we come to implement the future system whose DRGS services are closer to the original plan. We therefore estimate that the communication data capacity will remain at around 1.3 kilobytes at the most. This amount is within the range initially requested for use by DRGS as part of the total communication data amount allowed for UTMS.

TEST SCHEDULE FOR DRGS

In spring of 1996, we started to conduct verification tests on DRGS as it exists in the first stage. The tests is conducted within an square area having each side of about four kilometers in Tokyo, as shown in Figure 3. About 90 infrared beacons will be set up within the area and the DRGS services and algorithms are basically the same as those planned for use in the first stage. We also plan to use in-vehicle units produced by various manufacturers.

The main purpose of the verification tests is to check the various techniques required for DRGS using actual data. The tests consist mostly of off-line computer simulation and we plan to conduct various evaluations. The main details of the verification tests are described below.

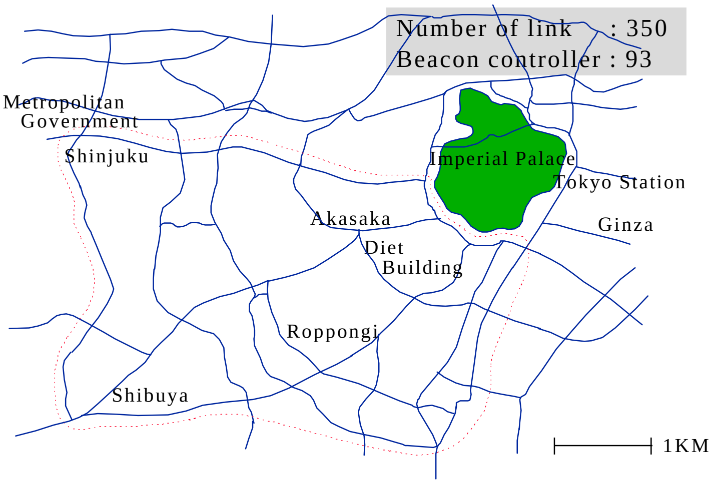

Figure 3 Experiment area of DRGS

Off-Line Simulation Tests

We simulate DRGS by a computer to evaluate route guidance in various ways using travel time obtained from vehicle detectors.

- We examine the suitability of the method of route selection and the required number of trees to be used as candidate routes.
- Each time the in-vehicle unit communicates with the infrared beacon, it receives updated route information and guides the vehicle based on this information. We evaluate whether the route provided is the optimum route or how suitable it is.
- We figure out the way to improve the response performance of route selection method, and evaluate feasibility of it.

Field Tests

We actually run vehicles equipped with in-vehicle units in the field and conduct various types of evaluation.

- We compare the static route guidance method used by various in-vehicle units with route guidance provided by DRGS.
- We evaluate the usefulness of the "multimode DRGS" in-vehicle unit which has been developed by various manufacturers.

Tests for Evaluating System Performance

We gather basic data to be used in developing the system and designing a system that embodies our final goal for DRGS in the future.

- Processing time of the center system
- Examination of methods to reduce transmission amount from the center to terminals
- Evaluation of the processing capacity of the infrared beacon

RESULTS OF OFF-LINE TESTS

We are now doing simulation tests, and report here on part of the evaluation for the method of route selection. In the simulation, the number of candidate trees was set to be eight, and evaluated for a particular origin and all destinations within a half circle radius of 10 to 20 km from it.

Diversity of Candidate Routes

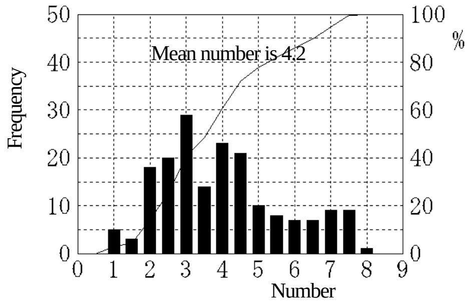

Figure 4 Number of candidate routes

The number of candidate routes for any O-D is not more than eight. That number means the number of possible routes alternated in accordance with a variety of traffic conditions, so is desirable to be as large as possible. Figure 4 shows the frequency histogram on the number of candidate routes to all destinations on the rule that a route whose consistency ratio to another route is less than 30 % is judged to be different from the route, where consistency ratio of route A to route B is defined as the proportion of length of route A consistent with route B for the whole length of route A. The mode number of candidate routes was around three and the average number was 4.2, widely considered good figures

Differences Between Near and True Optimum Routes

Figure 5 and 6 indicate the frequency histogram on the consistency ratios of near-optimum routes chosen among candidate routes to true optimum routes obtained without network restriction, and route travel time differences of both routes respectively. Where near-optimum routes were obtained using estimated travel time data of each link instead of predicted travel time data which could not be prepared for the simulation yet. The consistency ratio and route travel time difference were 81 %, 51 seconds on average respectively, that means a near-optimum route might be somewhat different from the true optimum route, but driving along the near-optimum route would not take much longer than driving along the true optimum route.

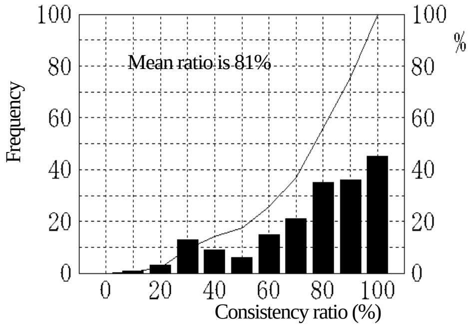

Figure 5 Consistency ratios of near to true optimum routes

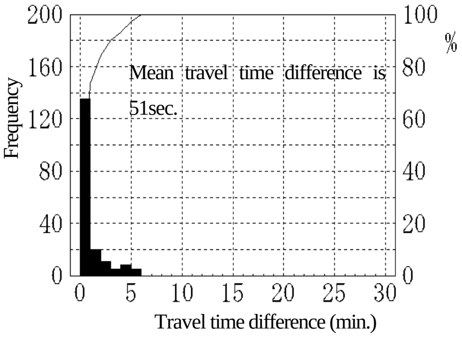

Figure 6 Route travel time differences between near and true optimum routes

CONCLUSION

We looked into the form that the interactive CDRG should take and designed the system to be adopted in the first stage. Since car navigation equipment is gaining popularity in Japan and traffic control systems have already been set up, we anticipate that DRGS, particularly the multi mode DRGS which incorporates CDRG and LDRG in a complementary combination, will prove to be a user-friendly route guidance system for drivers. We also created the method to select the optimum route with which a particular driver is provided. DRGS has been successfully tested since spring of 1996 and will become available in 1997 at the earliest.

ENDNOTES

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